

VU Research Portal

Socio-economic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh

Brouwer, R.; Aftab, S.; Brander, L.M.

2006

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Brouwer, R., Aftab, S., & Brander, L. M. (2006). *Socio-economic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh*. (Prem Working Paper; No. 06/01). Instituut voor Milieuvraagstukken.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Socio-economic vulnerability and adaptation to environmental risk

A case study of climate change and flooding in Bangladesh

Roy Brouwer¹, Sonia Aftab² and Luke Brander³

¹ Corresponding author. Institute for Environmental Studies (IVM), De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands, e-mail: roy.brouwer@ivm.falw.vu.nl

² North-South University, Department of Economics, Dhaka, Bangladesh

³ Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam, The Netherlands

Abstract

In this paper we investigate the complex relationship between environmental risk, poverty and vulnerability in a case study carried out in one of the poorest and most flood prone countries in the world, focusing on household and community vulnerability and adaptive coping mechanisms. Based upon the steadily growing amount of literature in this field we develop and test our own analytical model. In a large-scale household survey carried out in the south-east of Bangladesh, we ask almost seven hundred floodplain residents living without any flood protection along the river Meghna about their flood risk exposure, flood problems, flood damage and coping mechanisms. Novel in our study is the explicit testing of the effectiveness of adaptive coping strategies to reduce flood damage costs. We show that, as expected, households with lower income and less access to productive natural assets face higher exposure to risk of flooding. Disparity in income and asset distribution at community level furthermore tends to be higher at higher risk exposure levels, implying that individually vulnerable households are also collectively more vulnerable. Regarding the identification of coping mechanisms to deal with flood events, we look at both the *ex ante* household level preparedness for flood events and the *ex post* availability of community level support and disaster relief. We find somewhat paradoxically that the people that face the highest risk of flooding are the least well prepared, both in terms of household-level *ex ante* preparedness and community-level *ex post* flood relief.

PREM Working Paper: PREM 06/01

Keywords: Flood risks, social vulnerability, climate change, Bangladesh

Date: March 7, 2006

Table of Content

1. Introduction	1
2. Theoretical perspectives on vulnerability and adaptive capacity	2
3. The case study area	4
4. Survey set-up and sampling procedure	5
5. General floodplain resident characteristics	6
6. Flood problems and flood damage	8
7. Risk exposure and socio-economic vulnerability	10
8. Risk exposure and flood damage	11
9. Coping strategies and socio-economic vulnerability	15
10. Discussion and conclusions	18
References	20

Acknowledgements

The work presented in this paper is part of the Poverty Reduction and Environmental Management (PREM) programme funded by the Dutch Ministry of Foreign Affairs. We would like to thank the team of interviewers in Bangladesh who collected the data as part of this research. We are particularly grateful for the help and assistance provided by Wahid Abdulla, Sohel Atikuz-zaman, Enamul Haque and Sakib Mahmud. The usual disclaimer applies.

Poverty Reduction and Environmental Management (PREM)

PREM aims to deepen and broaden the exposure of economic researchers and policy advisors in developing countries to the theory and methods of natural resource management and environmental economics. It is envisaged that this will encourage effective policy change in developing countries with the joint goals of poverty reduction and sustainable environmental management.

This Working Paper Series provides information about the scientific findings of the PREM projects. All publications of the PREM programme, such as working papers, press releases and policy briefs are available on the website:

www.prem-online.org



Institute for Environmental Studies
Vrije Universiteit
De Boelelaan 1087
1081 HV AMSTERDAM
The Netherlands
Tel. +31 (0)20-5989 555
Fax. +31 (0)20-5989 553
E-mail: prem@ivm.vu.nl

1. Introduction

Bangladesh is a highly flood prone country. Eighty percent of the country consists of floodplains of the Ganges, Brahmaputra, Meghna and several other minor rivers. These floodplains sustain a predominantly poor rural population. Approximately 75 percent of the total population of 132 million people (in 2001) live in these rural areas, earning on average US\$325 per capita per year (Bangladesh Bureau of Statistics, 2005). Once every ten years roughly one third of the country gets severely affected by floods, while in catastrophic years such as 1988, 1998 and 2004 more than 60 percent of the country is inundated, that is an area of approximately one hundred thousand square kilometres for a duration of nearly three months (CEGIS, 2002). Floods cause social disruptions and result in scarcity of drinking water as surface water gets contaminated by organic and inorganic substances. Cases of diarrhea, cholera and other intestine diseases increase remarkably during and after floods.

The increased volume of rainfall caused by climate change during the past decades has intensified the flood problem in this part of the world. The population expected to be hardest hit by flood disaster is the poor people who lack adequate means to take protective measures and who also have very little capacity to cope with the loss of property and income (IPPC, 2001). A range of studies have recently focused on understanding how different groups of people and communities perceive and respond to flooding risks, especially in flood-prone countries in Asia, including Bangladesh (e.g. Schmuck-Widmann, 1996; Rashid, 2000; Rasid, 2000; Rasid and Haider, 2003). Since the mid 1990's, the concept of social vulnerability is used to describe and analyze the exposure and coping mechanisms of groups and individuals to environmental risks, primarily in the context of climate change and flooding hazards in developing countries (e.g. Blaikie *et al.*, 1994; Few, 2003).

In this paper, we build upon the steadily growing number of theoretical and empirical studies in the domain of social and economic vulnerability to environmental risk and assess household and community vulnerability and coping strategies to flood hazards in one of the poorest and most flood-prone countries in the world: Bangladesh. In a large-scale household survey carried out in 2005 in the south-east of Bangladesh, we ask almost seven hundred floodplain residents living without any flood protection along the river Meghna about their flood risk exposure, flood problems, flood damage and coping mechanisms. In addition, we carried out almost fifty semi-structured interviews with key informants at community level to address and assess community vulnerability to flooding.

The main objective of this paper is to investigate and provide further empirical evidence of the complex relationship between poverty and social and economic vulnerability in a concrete case study, focusing on individual household and community vulnerability and adaptive coping mechanisms. We show that, as expected, households with lower income and less access to productive assets face higher exposure to risk of flooding. Income inequality also plays a role in determining sources of collective vulnerability. Disparity in income and asset distribution at community level tends to be higher at higher risk exposure levels, implying that individually vulnerable households are also collectively more vulnerable. Regarding the identification of coping mechanisms to deal with flood events,

we look at both the *ex ante* household level preparedness for flood events and the *ex post* availability of community level support and disaster relief.

The remainder of this paper is organized as follows. Section 2 provides an overview of the theoretical concepts underlying social and economic vulnerability to environmental risk based upon the relevant literature in this field and presents our 'analytical model'. Section 3 introduces the case study, while section 4 discusses the set-up of the household survey and the key informant interviews. Section 5 presents the general floodplain resident characteristics and section 6 the flood related problems in the case study area. In section 7 we examine the relationship between risk exposure, socio-economic vulnerability and poverty, while section 8 looks further into the impacts of flood risks measured through flood damage in relation to poverty. Section 9 follows with the presentation and discussion of the effectiveness of *ex ante* and *ex post* coping strategies at household and community level in terms of their impact on flood damage. Finally, section 10 concludes.

2. Theoretical perspectives on vulnerability and adaptive capacity

There exists an increasing amount of literature about the operationalization of the concept of social and economic vulnerability to environmental risk. Generally, vulnerability is seen as the outcome of a mixture of environmental, social, cultural, institutional and economic structures and processes related to poverty and (health) risk, not a phenomenon related to environmental risk only. An extensive overview and discussion of recent theoretical and applied research on vulnerability and adaptive capacity in flood-prone areas is provided by Few (2003). Definitions of vulnerability focus on risk and risk exposure on the one hand and coping and adaptation mechanisms on the other (e.g. Pelling, 1999). Besides risk exposure, adaptive capacity is seen as a key component of the concept of vulnerability (e.g. Adger, 2000; IPCC, 2001). Empirical studies focus more and more on variations in both exposure to natural hazards and people's capacity to cope with these hazards (Few, 2003, p.48). Adaptive capacity is considered a process of adaptation (over time) to structural and/or incidental sources of environmental stress (e.g. Nishat et al., 2000), consisting of distinct social, economic, technological, institutional and cultural adaptive mechanisms (e.g. Cardona, 2001). Social mechanisms refer, for example, to social networks of relatives and neighbours, economic mechanisms to livelihood diversification or savings, technological mechanisms to technical measures to prevent flooding such as embankments or terps (mounds of earth), institutional mechanisms to (in)formal political-organizational structures and associated collective action to ameliorate vulnerability (including for instance access to productive assets or community micro-credit systems) and cultural mechanisms to perceptions and beliefs about the nature and avoidance of flooding.

Another distinctive feature of the concept of vulnerability is the level or scale of analysis. Variation in social and economic vulnerability to environmental risk can, for example, be explained at the level of the individual household or the community. In some studies, even national indicators are compiled and used (Vincent, 2004). Adger (1999) argues that individual vulnerability is determined by other factors than collective (community) vulnerability, but uses similar indicators for both levels of analysis (e.g. income (GDP) either measured at individual household level or at the level of a region or coun-

try). In this paper, we also distinguish explicitly between individual (household) and collective (community) vulnerability and we use similar indicators as the ones proposed by Adger (1999) in order to establish associations between risk exposure, poverty and what we label as *ex ante* and *ex post* adaptive coping mechanisms. We will show that the relationship between vulnerability and poverty is not as straightforward as expected. The poor are indeed more exposed to risks of flooding, but the claim that they are therefore also more likely than the wealthy to suffer when flooding strikes (e.g. Few, 2003) is rejected in our study.

The analytical 'model' of socio-economic vulnerability to flood risk exposure in our case study is shown in Figure 2.1. Central to the concept of vulnerability are, as mentioned, the exposure to risk and the adaptive capacity to risk.

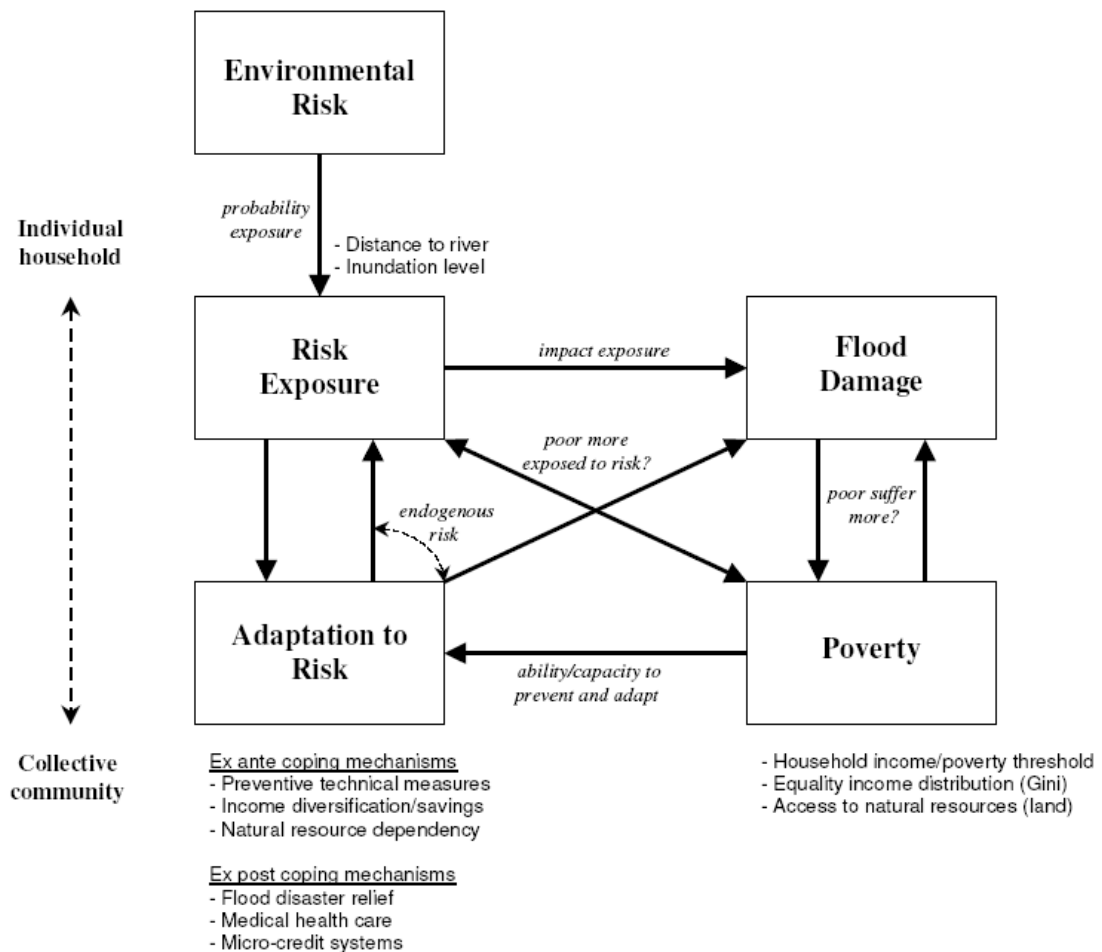


Figure 2.1 Analytical framework underlying the case study.

According to conventional risk theory (e.g. Shogren and Crocker, 1991; Smith, 1992), risk exposure consists of an exogenous and endogenous component as people are - to some extent - able to protect them self against (the negative impacts of) environmental risks, by avoiding the risk involved or by taking protective (preventive) measures before

being exposed to the risk or afterwards (e.g. insurance). Here, we subsume the endogenous component of risk under adaptation, and distinguish explicitly between *ex ante* and *ex post* coping mechanisms at individual household and collective community level. Following the seminal work by Knight (1921) and more recent expositions by, for example, Faber and Proops (1990) and Funtowicz and Ravetz (1992), we furthermore distinguish explicitly between the likelihood of being struck by flooding (probability of exposure) and the impact of flooding (measured through damage cost). These are considered two separate dimensions of the concept of risk, where risk is defined as the (objective or subjective) probability of reaching a future state or outcome and the expected consequences of this state or outcome (e.g. Costanza, 1994). Here, we refrain from attaching probabilities to flooding (flooding being an annual event) and simply measure (i) the probability of risk exposure through the distance (in kilometres) people live to the river at community level (the closer to the river, the higher the probability of flooding), (ii) the state or condition of risk exposure through inundation depth (in feet) at individual household level, and (iii) the consequence of risk exposure through economic damage cost (local currency converted to US\$) when the flooding occurs at individual household level.

Poverty is both an important determinant of (endogenous) environmental risk - and hence (in)directly of socio-economic vulnerability - and an important constraint of adaptive capacity. Poorer people tend to be more (often) exposed to environmental risk than wealthy people. The latter are furthermore able to take protective measures or are able to avoid certain environmental (health) risks, i.e. the endogenous component of risk. Conventional poverty indicators (e.g. Blackwood and Lynch, 1994) used in this study include annual household income compared to the official poverty threshold value calculated by the Bangladesh Bureau of Statistics, income distribution at community level (measured through Gini coefficients) and household access to and ownership of natural resources, most importantly in this case study land for crop cultivation.

3. The case study area

The case study is carried out in a low-lying, severely flood prone fluvial delta located in the south-east of Bangladesh in the district of Homna, approximately 70 km from Dhaka. The floodplain delta covers an area of approximately ten thousand hectares and is bordered in the north-west by the Meghna river, its tributaries the Titas river in the north and south and the Kathalia river in the west (Figure 3.1).

More than four hundred thousand people live in the area (2001 population census). Most of them are farmers. Almost three quarters of the land is used for farming, mainly rice. Other crops include wheat, vegetables, pulses, oil seeds and maize. Some livestock farming is also present, but on a very small scale. Communities of fishermen are found along the rivers. Furthermore, many creeks and canals are found in the area, which are also utilized for fishing.

The area's topography varies between 1.5 and 4.0 meter above sea level. Average annual rainfall is 2,025 ml of which 75% falls during the monsoon from June to October. Heavy monsoon rainfall generates excessive flows in the rivers and thereby causes floods almost every year. These floods cause damage to houses, agricultural crops and the infrastructure in the area. For more than half of the rain season around two thirds of the area

remains under six feet water. As a result, employment opportunities decrease dramatically. Around 80 percent of the labour force is unemployed during the flood season.

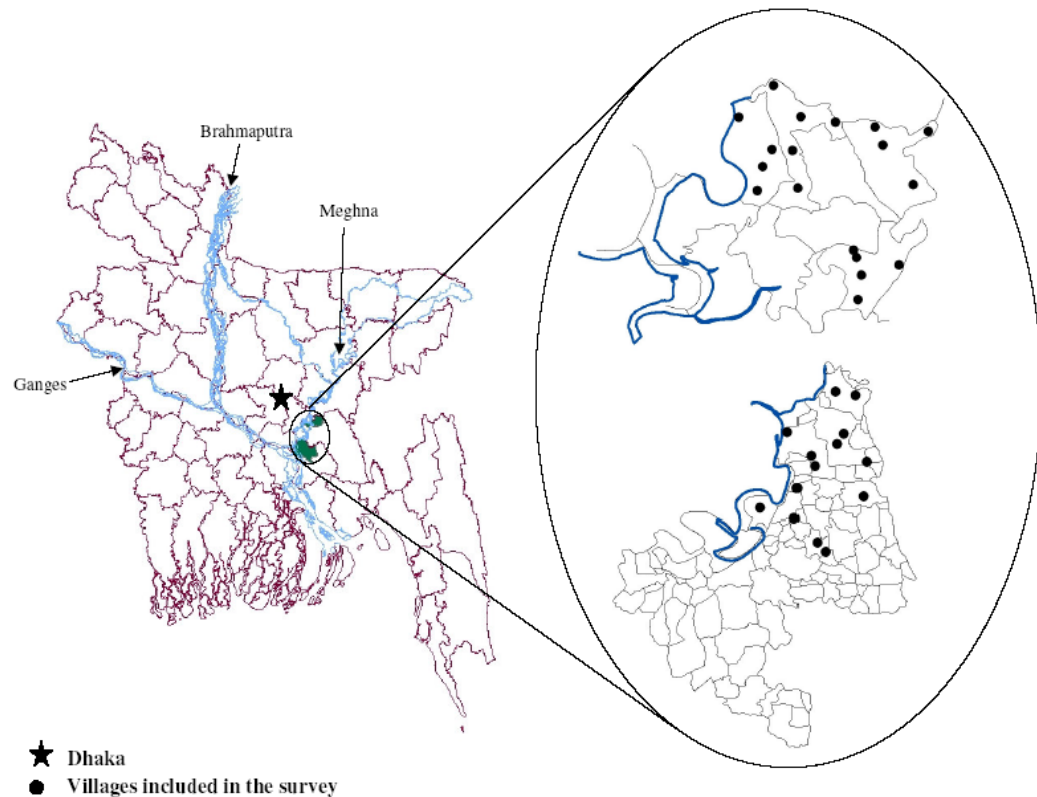


Figure 3.1 Location of the case study area in Bangladesh.

In addition to regular seasonal flooding, the area suffered from devastating floods over the past 20 years in 1988, 1996, 1998 and 2004. During the 2004 flood, Homna was identified in the Rapid Flood Assessment as one of the most severely affected areas in Bangladesh in terms of percentage of area inundated, inundation depth (≥ 2 meter) and percentage of people affected (Centre for Policy Dialogue, 2004).

4. Survey set-up and sampling procedure

The study presented here was part of a wider, extensive rural household survey looking at agricultural and fish production systems in flood plains, general demographic, socio-economic characteristics of floodplain residents and flood problems in one of the most severely flood prone areas in Bangladesh.

A total of 672 people were interviewed face-to-face from the last week of March until and including the second week of May 2005 by local (male and female) interviewers.¹

¹ The interviewers were carefully selected and thoroughly trained in view of the low education level of respondents and the high illiteracy rate in the area. The same interviewers were also used for the pre-testing of the questionnaire. Three pre-test rounds were used to finalize the household questionnaire over a period of two and a half months, including a one-day workshop with local experts and stakeholders.

Each interview lasted on average 30 minutes. A stratified sampling procedure was used where 32 villages were chosen based on their distance from the river Meghna (Figure 2). In each of these 32 villages every fifth house along one side of the main village road was selected in the sample.

The questionnaire consists of five sections, two general sections and three sections designed for specific occupational activities (including household production and consumption patterns). Hence, each respondent answered three sections: a general introductory section, including questions about respondent demographic and socio-economic characteristics, a section specifically dealing with flood and flood control issues, and an occupational section. For a more detailed description of the survey design, the interested reader is referred to Haque et al. (forthcoming). The flood related questions are aimed at examining the extent and nature of the impacts of flooding on life and livelihood (including inundation frequency and depth, health related impacts and damage costs) and floodplain residents' perceptions regarding the management and funding of a proposed flood alleviation scheme in the area.

In addition to the household survey, 45 semi-structured key informant interviews were carried out from the second week of April to the second week of May 2005. On average, each key informant interview lasted for one and a half hours. The semi-structured questionnaire covered the impact of flooding on different occupational groups, coping mechanisms during and after a flood, and information regarding household activities during normal and extreme flood years. Besides some quantitative information, the key informant interviews were primarily qualitative in nature. Where necessary interviews were adapted to different professional backgrounds of the interviewee. Local primary school teachers, leaders from fishing communities, agricultural extension officials, health workers and NGO workers were interviewed. The interviews were conducted by local college teachers, who were very knowledgeable about and familiar with the specific local situation and circumstances, and well informed and trained about the main objectives of the interviews.

Finally, in a small-scale survey carried out six months after the original survey (in November 2005), face-to-face follow-up interviews were conducted with eighty-nine randomly selected respondents who also participated in the original large-scale rural household survey (13% of the original sample population). In this follow-up survey, respondents were asked more specifically about the type of preventive measures they take to protect themselves against flooding and the reasons why a large proportion of the sample population does not take any preventive measures. Also these results will be reported here and are used in the overall analysis.

5. General floodplain resident characteristics

Table 5.1 summarizes the general demographic and socio-economic characteristics of the 672 households included in our sample. Most of the floodplain respondents are Muslim men, who are the head of their household (75%). Most people interviewed (97%) were furthermore born and raised in the region. The average age of respondents is around 40 to 45 years. About half of the interviewed respondents were unable to read and write. Just over a quarter finished primary school and just over ten percent finished high school. The households consist, on average, of 6 people, of which two (usually men)

earn income. The household size found in our sample corresponds with the national household situation in Bangladesh.

Table 5.1 Summary statistics of respondent (household) demographic and socio-economic characteristics.

Respondent (household) characteristic		Value
Percentage male respondents in sample		85.4
Respondent average age (median value)		42 (40)
Respondent religion (%)	Muslim	89.0
	Hindu	11.0
Literacy rate respondent (%)	Illiterate	51.9
	Primary school	27.9
	High school	12.6
Respondent occupation (%)	Self-employed farmer	43.0
	Self-employed fisherman	19.0
	Day labourer	19.0
	Ferry/taxi worker	14.2
Average number of family members (min-max)		6.3 (2-20)
Average number of adults (min-max)		4.1 (2-13)
Average number of children (min-max)		2.2 (0-11)
Average household income (US\$/year) (st. dev.)		954 (1245)
Average per capita income (US\$/month) (st. dev.)		14.5 (20.3)
Percentage households dependent on NRDI*		25.1
Percentage households under poverty threshold**		48.5
Income inequality (Gini coefficient)		0.466
Percentage households owning agricultural land		59.4
Average size land owned by household (ha)		0.33
Percentage households owning fish pond		18.7
Percentage with pacca latrine sanitary facility		71.3
Percentage with electricity connection		37.8
Percentage with telephone connection		5.4
Percentage tubewell as main drinking water source		97.8
Main sources of household energy (%)	Twigs/leaves/straw/dung	58.8
	Coal	38.2
Percentage of which house area gets inundated		95.5
Average annual flood damage (US\$) (st. dev.)		198 (672)
Percentage of annual household income		20.8

* Natural Resource Dependent Income (NRDI) is defined as income originating from agriculture (crop cultivation), fishery or aquaculture.

** The Bangladesh Bureau of Statistics calculates the so-called Basic Cost Need as a poverty threshold value. This threshold value was US\$105/capita/year in 2004.

Most households are involved in agricultural activities to support their livelihood. Approximately 20 percent of the sample population consists of day labourers². Almost all households own the house they live in, and 60 percent owns the land they grow their

crops on. Almost all houses are made of tin (both roof and walls) and a water-sealed latrine is the most important sanitary facility in dwellings. About one in every third household has electricity. Most households get their drinking water from a private or collective tube well and use leaves and cow dung as their main source of energy.

There is a wide spread in annual household income, as can be seen from the standard deviation in Table 5.1 and the Gini coefficient calculated for the sample population. Average annual household income (related to the past 12 months) is about US\$950, while half of the sample population earns US\$585 per year. Average annual per capita income is US\$175, which is substantially lower than the national average (US\$325). Using the Basic Cost Need (BCN) calculated by the Bangladesh Bureau of Statistics as the poverty threshold (US\$105 per capita per year), almost fifty percent of the floodplain residents included in the sample appear to live below this poverty line. A further distinction can be made between natural resource dependent and non-natural resource dependent income. A quarter of the interviewed floodplain residents are fully dependent for their income on (access to) natural resources such as agriculture and fishery (including aquaculture).

6. Flood problems and flood damage

A majority of 96 percent of the interviewed floodplain residents are exposed every year during the rainy season to flooding, and a quarter of the population mentions flooding as the main problem faced by the region, followed by other important problems such as bad roads (23%), unemployment (20%) and lack of electricity (17%). The extent of flood exposure during the rain season is presented in Figure 3. In more than one third of the cases the water comes waist high during the rain season (approximately 1.5 feet) and in another one third of the cases even shoulder high (approximately 3 feet). Almost half of the population (46%) indicates that they suffer each year from diarrhea during the rain season. Ninety-nine percent seeks medical treatment for this.

² The distribution of respondents across occupational groups is not representative. Relatively more fishermen were interviewed in the rural household survey for the estimation of fishery production functions. However, when taken together, the group of fishermen and farmers in the sample is more or less representative for the whole rural population in Bangladesh (60% of the rural population is full time farmer or fisherman).

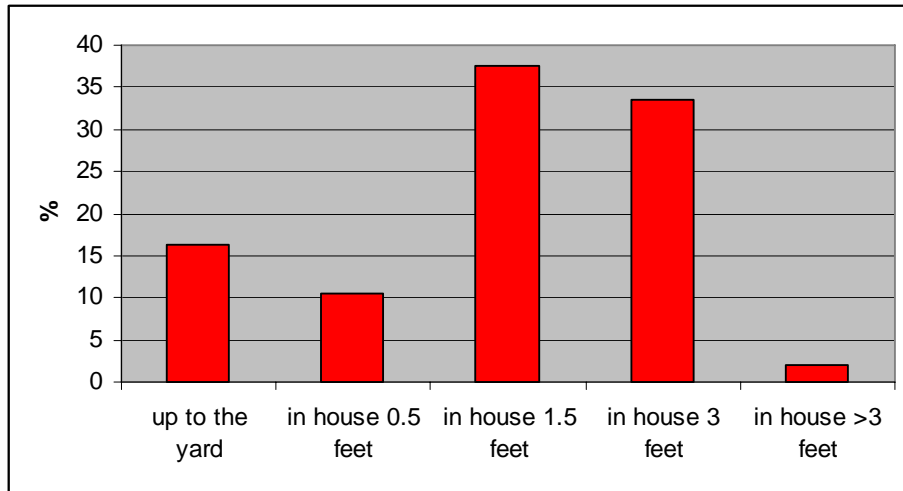


Figure 6.1 Percentage of households suffering from flood at different inundation levels.

Average flood damage costs are almost US\$200 per household per year. This amounts to approximately 20 percent of average household income. Median damage costs are half of this amount (US\$95). Dividing this by the median value for household income, the share of damage in household income is slightly lower, namely 16 percent. The minimum damage costs are zero and the maximum US\$16,000. Trimming off the five percent lowest and highest values, the average damage cost estimate is US\$140 per household per year. Most flood damage is caused by property and crop damage, followed by damage to fishponds (loss of fish stock) (see Figure 6.2). The other damage category includes loss of income from day labour and trade.

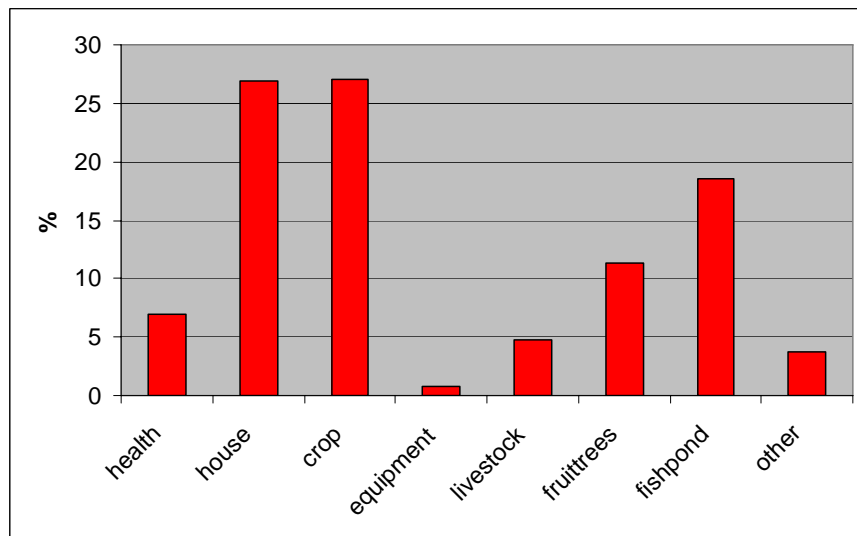


Figure 6.2 Relative contribution of different damage categories to total household damage costs.

7. Risk exposure and socio-economic vulnerability

As expected, there exists a significant positive relationship between the distance people live from the river Meghna as an indicator of (collective) risk exposure and household income (Table 7.1). Floodplain residents living in villages that are situated further away from the river have higher income levels. Interestingly, a significant negative relationship is found between distance and income distribution (as measured through Gini coefficients at village level). Villages situated further away from the river have more equal income distributions (the lower the Gini coefficient, the more equal the income distribution).

Table 7.1 Correlation between distance to river as an indicator of risk exposure, household income and income distribution

	Distance to river Meghna
Household income	0.113 ($p < 0.003$) 663
Equality of income distribution (Gini ratio)	-0.246 ($p < 0.001$) 672
Explanatory note:	Spearman rho (two-tailed significance) number of observations

Relating inundation depth as another indicator of risk exposure at individual household level to household income, we find a small, but significant negative relationship, suggesting that lower incomes suffer higher inundation levels and are hence indeed more exposed to flood risks. The same significant negative relationship is also found between inundation depth and land ownership. Those respondents who own more land suffer lower inundation levels. This is visualized in Figure 7.1 (the underlying correlation table is presented in the annex to this paper). As expected, land ownership is significantly and positively correlated to household income ($r = 0.331$; $p < 0.001$). People with higher income own more land.

These results are confirmed when comparing the same risk exposure indicator for respondents living under and above the poverty threshold value (see section 5.1). Floodplain residents living under the poverty threshold value face significantly higher inundation levels than floodplain residents living above the poverty threshold value (Table 7.1). At the same time, floodplain residents living under the poverty threshold depend for their livelihood significantly more on natural resources such as land for crop cultivation and fishery than floodplain residents living above the poverty line (Table 7.2) ($\chi^2 = 9.162$; $p < 0.002$), even though they own, for instance, significantly less land (Table 7.1).

Fig. 7.1a

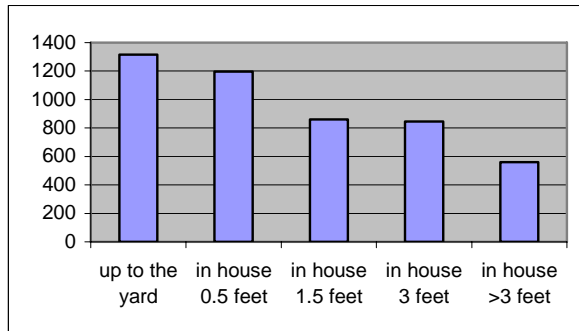


Fig 7.1.b

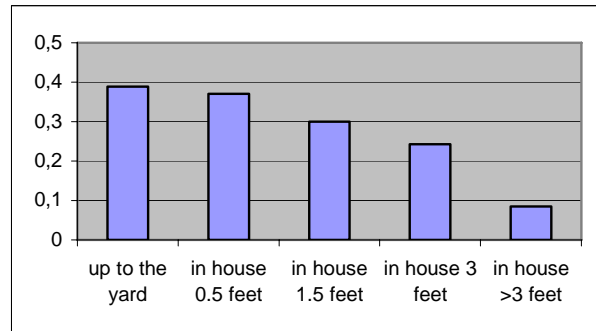


Figure 7.1 Relationship between inundation depth and household income (US\$/year) (Fig. 7.1a) and inundation depth and landownership (ha) (Fig. 7.1b).

Table 7.1 Differences between floodplain residents living under and above the poverty threshold value in terms of inundation level and landownership.

	Below poverty threshold	Above poverty threshold	MW test Z-statistic (2-tailed sig.)
Inundation level (0-5)	3.19 (0.949)	2.82 (1.103)	-4.540 (p<0.001)
Landownership (ha)	0.29 (1.20)	0.36 (0.49)	-3.606 (p<0.001)

Explanatory notes:

a. Mean values (standard deviations in parentheses)

b. MW: Mann-Whitney test

Table 7.2 Cross tabulation number of floodplain residents living under and above the poverty threshold and number of flood plain residents whose income depends fully on natural resources (land for crop cultivation and fishery).

	Below poverty threshold	Above poverty threshold	Total
Household income fully dependent on natural resources	14.7% (n=99)	10.4% (n=70)	25.1 (n=169)
Household income not fully dependent on natural resources	33.8% (n=227)	41.1% (n=276)	74.9% (n=503)
Total	48.5% (n=326)	51.5% (n=346)	100% (n=672)

8. Risk exposure and flood damage

As expected, the consequences of risk exposure, measured through economic damage costs, are negatively correlated with the distance from the river. However, this correlation is not statistically significant at the conventional 5 or 10 percent level ($r=-0.055$; $p<0.17$). Comparing the damage costs across different inundation levels, we find that the damage costs are more or less the same at lower inundation levels, but increase as inun-

dation depth increases (Figure 8.1). The outcome of the Kruskal-Wallis test confirms that this increase is statistically significant ($\chi^2 = 9.626$; $p < 0.05$).

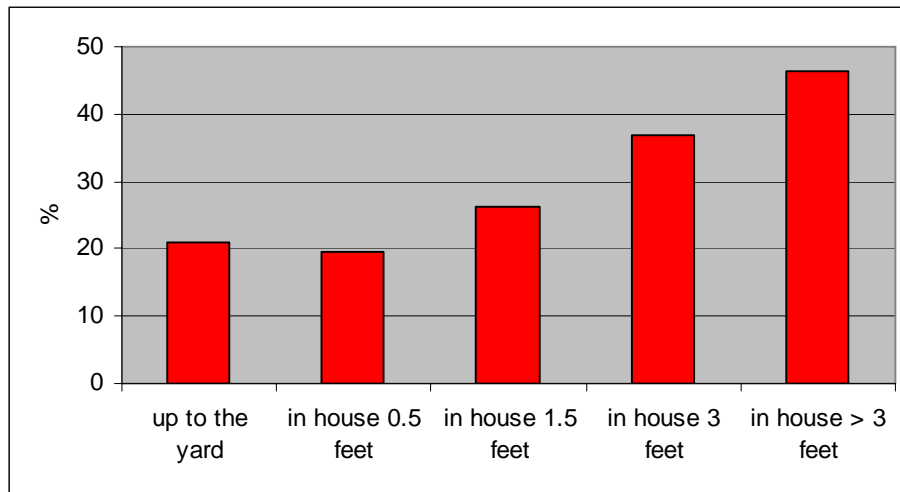


Figure 8.1 Relationship between average annual damage costs as a percentage of annual household income and inundation level.

The relationship between poverty and the consequences of the environmental risk involved proves rather complex. We test the hypothesis that the poor suffer most from being exposed to environmental risk by further examining the relationship between flood damage and income, income distribution, income dependency on natural resources and access to these natural resources (Table 8.1). Damage costs appear to be significant and positively correlated with household income, at individual household and village level, suggesting that floodplain residents who are better off in economic terms also are most sensitive and vulnerable to suffer economic damage. Although this finding rejects the hypothesis that the poor usually suffer most when faced with a natural disaster, the result seems perfectly plausible. The more one has, the more can be lost or is at stake to be lost.

The results are confirmed when examining average damage costs between floodplain residents living under and above the poverty threshold. Although the former face significantly higher inundation levels (see Table 7.1), they have slightly, but significantly lower (absolute) average damage costs (Table 8.2). However, in relative terms compared to annual household income, the share of annual damage costs is significantly higher for floodplain residents living under the poverty threshold than for floodplain residents living above this threshold. This latter finding confirms the mentioned hypothesis.

Table 8.1 Correlation between flood damage as an indicator of the impact of risk exposure and various poverty indicators.

	Flood damage costs
Household income	0.412 ($p < 0.001$) 636
Equality of income distribution (Gini ratio)	0.176 ($p < 0.001$) 645
Land ownership	0.409 ($p < 0.001$) 645
Natural resource dependent income	0.430 ($p < 0.001$) 645
Explanatory note:	Spearman rho (two-tailed significance) number of observations

Average flood damage costs vary significantly across different occupational groups (Kruskal Wallis $\chi^2 = 72.250$; $p < 0.001$). Fish cultivators suffer most damage (US\$307) as a result of flood damage to artificial ponds and loss of fish stock, followed by farmers (US\$227) and tradesmen (US\$209). Although still substantial, the damage suffered by other occupational groups (ferryman, taxi drivers and day labourers) is significantly less (US\$95). This finding corresponds more or less with the results presented earlier in Figure 4 in section 6, showing that crop damage, house property damage and fish loss are the most important damage cost categories. The distribution of flood damage across occupational groups slightly changes when we examine relative damage costs. The share of flood damage relative to household income appears to be highest for farmers (35%), followed by fishermen (32%). This percentage is more or less the same for the other occupational groups (20%)³.

At community level, greater income inequality appears to result in higher flood damage costs, suggesting that policy pursuing income equality may also have important economic benefits in terms of avoided damage costs in a flood prone country such as Bangladesh. This finding furthermore confirms the hypothesis that vulnerability is determined - *inter alia* - by income inequality (e.g. Adger, 2000).

Corresponding with the result found for damage and income, the more assets someone owns (i.e. land for crop cultivation) and the higher the share of natural resources in in-

³ The different occupational groups earn significantly different incomes (Kruskal Wallis $\chi^2 = 39.108$; $p < 0.001$). Tradesmen have the highest annual household income (US\$1,490), followed by farmers and fishermen, who have more or less the same household income (respectively US\$1095 and US\$1060 per year), and ferryman, taxi drivers and day labourers, who also earn more or less the same (respectively US\$670, US\$640 and US\$645 per year).

come generation (agriculture and fishery), the higher the damage costs involved as a result of flooding (Table 8.1)⁴.

Table 8.2 Differences between floodplain residents living under and above the poverty threshold value in terms of absolute and relative flood damage costs.

	Below poverty threshold	Above poverty threshold	MW test Z-statistic (2-tailed sig.)
Average inundation level (0-5)	3.19 (0.949)	2.82 (1.103)	-4.540 (p<0.001)
Average flood damage (US\$/year)	191 (928)	204 (242)	-4.791 (p<0.001)
Average flood damage as share of household income (%)	41.6 (103.1)	16.6 (18.9)	-6.399 (p<0.001)

Explanatory notes:

- a. Mean values (standard deviations in parentheses)
- b. MW: Mann-Whitney test

However, for floodplain households that fully depend on natural resources (poorer segment in the floodplain sample) we find on the other hand that their absolute and relative damage costs are significantly lower than for households who do not fully depend on natural resources such as agriculture or fishery for their livelihood (Table 8.3). Whether this suggests that income diversification is not an effective vulnerability coping strategy will be discussed in the next section.

⁴ The hypothesis that the more assets people have, the less vulnerable they are (Moser, 1998, p.3) cannot be tested here in view of the fact that the current study merely provides a snapshot of reality. In order to test the hypothesis that asset erosion results in more insecurity and hence vulnerability can only be tested through time series analysis of the sample.

Table 8.3 Differences between floodplain households fully dependent on and floodplain residents not fully dependent on natural resources in terms of absolute and relative flood damage costs.

	Fully NR dependent	Not fully NR dependent	MW test Z-statistic (2-tailed sig.)
Average inundation level (0-5)	3.23 (0.98)	2.93 (1.05)	-3.159 (p<0.002)
Average flood damage (US\$/year)	94.9 (139.8)	231.9 (770.5)	-6.244 (p<0.001)
Average flood damage as share of household income (%)	20.7 (29.0)	31.6 (84.0)	-2.159 (p<0.03)

Explanatory notes:

- a. NR: natural resources (agriculture and fishery)
- b. Mean values (standard deviations in parentheses)
- c. MW: Mann-Whitney test

9. Coping strategies and socio-economic vulnerability

Flood damage costs can be mitigated by measures aimed at preventing, avoiding or alleviating the physical and socio-economic impacts of flooding. As mentioned in section 2 (Figure 2.1), we distinguish between ex ante and ex post coping mechanisms at individual and collective level. Following the results presented at the end of the previous section, we start with the ex ante adaptation strategy of income diversification (e.g. Few, 2003). This will be followed by a discussion of ex ante prevention measures at individual household level and we will end this section with a presentation of ex post coping mechanisms at community level.

When relating flood damage costs to the number of income sources, we find an interesting trend, where an increase in income sources seems to go hand in hand with lower average damage costs (Figure 7). The observed trend is furthermore statistically significant at the one percent level (Kruskal-Wallis $\chi^2 = 14.325$; $p < 0.006$). The flood damage costs increase significantly from one to two income sources, but decrease gradually from there onwards, suggesting that income diversification is indeed an effective coping strategy.

At the village level income diversity appears to be significant and positively correlated with the distance people live from the river Meghna ($r = 0.209$; $p < 0.001$). Households living further away from the river not only have more income (and income is more equally distributed), they also have significantly more sources of income. Hence, at household level the relationship between flood damage and income diversity suggests that the latter is an effective coping mechanism to environmental risk, but at village level communities that face the highest risk of flooding seem to be the least well prepared.

Turning to preventive (ex ante) measures, a majority of 86 percent of the floodplain residents interviewed in the follow-up survey (see section 3) take no preventive measures for a variety of reasons. Most importantly, because they have insufficient financial means to protect themselves against flooding (45%), followed by not knowing which type of measures to take (30%) and the belief that flooding is a natural process which cannot be

prevented (21%)⁵. Floodplain residents taking preventive measures, primarily through land elevation works, earn significantly higher incomes and have significantly lower damage costs (also in relative terms) (Table 8). Hence, taking preventive measures pays off as it significantly reduces annual flood damage costs, but their implementation seems to be significantly constrained by limited income resources.

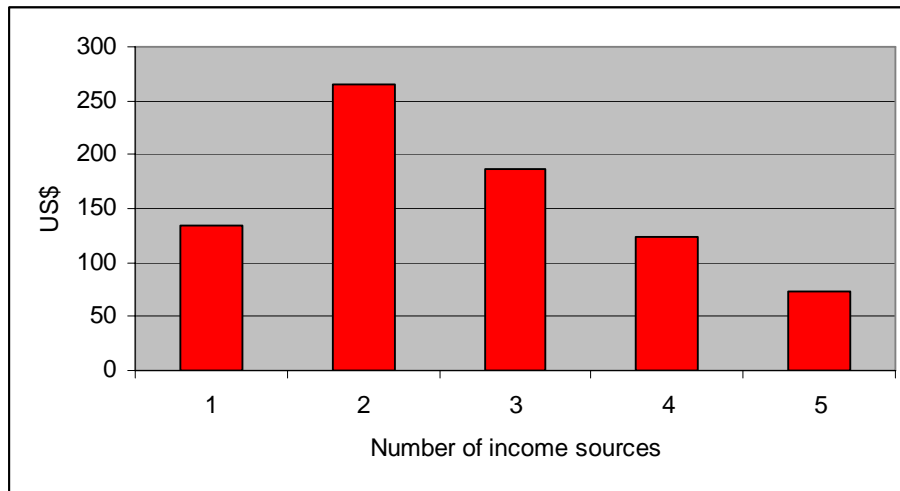


Figure 9.1 Relationship between average flood damage cost and number of income sources.

When asking floodplain residents in the original sample about their attitudes towards flood protection, 80 percent of all respondents say that they consider flood protection (very) important. Thirteen percent believe this is not important. Interestingly, comparing floodplain residents who consider flood protection not important with those who believe this is (very) important, the latter live significantly further away from the river than the former and earn significantly more income⁶. However, in the case of inundation depth during floods and annual flood damage the relationships are as expected, i.e. those who believe flood protection is (very) important face significantly higher inundation depths during the rainy season and suffer significantly more damage⁷.

In the follow-up sample, floodplain residents were also asked which type of embankment they prefer. A majority of 53 percent prefers controlled flooding, i.e. a submerged embankment in the river, which allows the whole area to flood regularly, but protects the area from extreme floods (flood disasters). About one in every fifth floodplain resident (22%) prefers a completely closed embankment (no flooding at all) and an equal number of floodplain residents (21%) have a preference for a partly closed embankment, which allows only certain parts of the area to be flooded every year. No large differences were found here between floodplain residents who already take preventive measures and those

⁵ The remaining 4 percent indicated not to suffer from flooding.

⁶ The Mann-Whitney Z statistic equals -1.881 ($p < 0.06$) in the case of household income and -3.462 ($p < 0.01$) in the case of distance from the river.

⁷ The Mann-Whitney Z statistic equals -6.436 ($p < 0.01$) in the case of inundation depth and -4.255 ($p < 0.01$) in the case of annual flood damage.

who do not⁸. Similar results have been found by Rasid (2000), who showed that a majority of floodplain residents – mainly farmers – prefer regulated flood levels instead of total flood prevention, where the preferred level of inundation corresponds with the ideal flood depth for the cultivation of floodplain rice.

From the key informant interviews, it appears that the existence of social networks or an institutional set-up in the area for a more collective *ex ante* or *ex post* coping strategy to flooding is very thin. Moreover, no differences between villages in this poor and severely flood struck can be detected in terms of formal or informal institutional arrangements to cope with flood hazards within the community⁹. Flood affected poor families are allowed to take shelter in village schools or higher local government buildings, where they can stay as long as the area remains flooded (weeks/months). Families who lose their home and livelihood and remain without savings or other sources of income can move to flood relief camps in the district (upazilla) headquarters, which are usually set up and managed by local government. Most of the flood-affected people barely have any savings or food stocks. Based on the 2004 regional flood report (LCG Bangladesh, 2004), it was estimated that flood affected floodplain residents required food-aid for between 150 to 180 days as they did not have any possibilities of income generation until the next harvesting season.

Also the existence of formal credit institutions to help rehabilitate flood struck households in the study area is rare. Flood affected families mainly cope with a flood crisis with the help of informal credit. Relatives, neighbours and family friends help flood affected families by providing loans and other assistance, or flood affected families buy food from local shops on a credit basis. Sometimes richer, well-off families in a village lend money to flood affected local residents. A number of leading non-government organizations (NGOs) that mainly deal with micro-credit also operate in the study area. Although existing literature suggests that NGOs such as the Bangladesh Rural Advancement Committee (BRAC) play an important role in *ex-post* coping response to flood disasters by distributing flood relief, agricultural inputs and subsidized micro-credits in flood affected regions in Bangladesh (Zaman, 1999), most key informants in this particular area stated that these NGOs play almost no role at all. Most flood-affected families depend on relatives, neighbours and informal micro-credit systems to cope with floods.

A study based upon survey data collected after the 1988 flood disaster (Haque and Zaman, 1994) furthermore shows that around 70 percent of the affected farmers in Bangladesh mitigated their income and asset losses by selling land, livestock and other belongings. This was not observed in our case study, or mentioned by the key informants as an effective common coping strategy, possibly because of the fact that many floodplain residents in this specific case study area are so poor (half of the sample lives under the poverty threshold) that they have insufficient income or assets to sell at all.

⁸ When asking respondents who they believe is responsible for flood control in their area and who should pay if an embankment was to be constructed to protect the area from flooding, a majority of eighty-two percent refers to the central Government, followed by foreign aid agencies (12%). Less than five percent believes that the local residents self should pay.

⁹ In certain parts of Bangladesh, which are protected by embankments, the existing flood protection schemes are successfully operated and managed by local stakeholders who are organized in cooperatives (Quassem, 2001).

Finally, we also investigated possible migration patterns as a result of flood related problems in the case study area. About a quarter of the sample have relatives that moved outside the area in the past 15 years, mainly because of economic considerations (e.g. work in Dhaka or abroad). When asked, only 2 percent said that the main reason for moving is directly related to the flood problems experienced in the area. This seems to imply that migration is not considered a direct coping mechanism. However, given the negative relationship between the physical conditions in the area (severely flood prone) and the area's economic development (one of the poorest regions in Bangladesh) and the substantial share of remittances in total household income (16%), it is our opinion that migration does play a role as a flood coping mechanism in combination with income diversification.

10. Discussion and conclusions

In this paper, we investigated the complex relationship between environmental risk, poverty and vulnerability in a concrete case study carried out in one of the poorest and most flood prone countries in the world, focusing on household and community vulnerability and adaptive coping mechanisms. Building upon the growing theory and empirical evidence regarding these relationships, we produced our own simple analytical model and tested relationships between the model's core variables in (as far as possible) a systematic way, using data and conventional indicators from a large-scale survey of households in rural Bangladesh. Although a number of studies have been carried out in Bangladesh looking at poverty and flood coping strategies, such a systematic examination of the concept of socio-economic vulnerability is currently lacking. The case study area is situated in one of the poorest and most flood-prone areas of Bangladesh, making it an ideal case for further testing of the mentioned relationships. Novel in our study is furthermore the explicit testing of the effectiveness of existing preventive and adaptive coping strategies in terms of their impact on flood damage costs.

Our results confirm the positive relationship between environmental risk, poverty and vulnerability. Poorer segments of society live closer to the river, therefore face a higher risk of flooding and are thus more vulnerable, and we were able to show that actual inundation levels are indeed significantly higher for poorer households. At the same time, environmental risk exposure also goes hand in hand with income inequality and access to natural resources: the higher the exposure level, the higher the inequality and the less access a household has to land. Inequality also results in higher flood damage, confirming the hypothesis found in the literature that an unequal income distribution contributes to socio-economic vulnerability. However, the relationship between poverty and damage costs (and hence vulnerability) appears to be more complex than the literature suggests. The poor suffer more in relative terms, but not in absolute terms. Average damage costs in absolute terms are significantly higher for wealthier households. Moreover, their coping capacity is as expected also greater than poorer households, reflected by the fact that the relative proportion of the flood damage costs in total household income is significantly lower for wealthier families. Farmers and fish cultivators suffer most damage, both in absolute and relative terms. Approximately one third of their annual household income is lost due to flooding.

Floodplain households that fully depend on natural resources for their livelihood (the poorer segments in society) suffer significantly less damage, but from our analysis we conclude that this does not exclude income diversification as an effective flood coping strategy. On the contrary, more income sources appear to result in lower average damage costs, suggesting that spreading the environmental risk across multiple economic activities pays off. However, we find that income diversification is primarily a strategy followed by wealthier families and communities living further away from the river. Families living nearer to the river seem to have fewer opportunities to engage in multiple economic activities, which makes them more vulnerable to natural disasters, and may keep them trapped in a poverty cycle (see for example Chambers, 1995). The latter conclusion cannot be further substantiated in this study as the study merely provides a snapshot of the current situation. A more detailed time series analysis is required to test the hypothesis that poorer segments in society depending on just one or two natural sources of income are trapped in a downward poverty spiral. A similar situation is observed for preventive measures. Floodplain households taking preventive measures earn higher incomes and have significantly lower damage costs in absolute and relative terms. Also the implementation of preventive measures is constrained by limited financial resources, although a substantial proportion of floodplain residents do not take any preventive measures because they believe that flooding is a natural process, which cannot be prevented.

Regarding the availability of ex post disaster relief, we used information from semi-structured key informant interviews to assess the existence of social networks and institutional arrangements to support flood victims. It appears that the availability of such community level support is generally rather low, although some degree of flood relief exists in the form of loans to flood victims from family members, neighbours, rich members of the community and credit for food from local shops. Using the assumption that communities with a more equal income and wealth distribution are more likely to have social networks to provide flood relief, we find that villages with higher risk exposure also have more unequal income distributions, suggesting that they have a lower provision of community level organization to cope with flooding. We therefore find, somewhat paradoxically, that the people that face the highest risk of flooding are the least well prepared, both in terms of household-level ex ante preparedness and community-level ex post flood relief. There is clearly a need for more government involvement to either provide further flood protection and flood relief directly, or to stimulate household and community level efforts to protect and support flood victims. Moreover, policies that pursue income equality may also be effective in that they will have important economic benefits in terms of avoided damage costs.

As a final methodological note we want to emphasize that the analysis presented in this paper is primarily based on observed associations and relationships, using linear correlations and non-parametric testing procedures. An important question remains how much the observed relationships actually tell us about underlying (non-linear) causal relationships as suggested for example by Adger (1999), and in which direction these causal relationships act. We believe that a more extended deterministic model is needed to further test these underlying causal relationships and their direction in future research in this domain.

References

- Adger, W.N. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27(2), 249–69.
- Adger, W.N. (2000). Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers* 90(4), 738–58.
- Bangladesh Bureau of Statistics (2005). *Statistical pocketbook of Bangladesh 2003*. Bangladesh Bureau of Statistics, Dhaka.
- Blackwood, D. L. & Lynch, R. G. (1994). The measurement of inequality and poverty: A policy maker's guide to the literature. *World Development* 22(4), 567–578.
- Blaikie, P., Cannon, T., Davis, I. & Wisner, B. (1994). *At risk: natural hazards, people's vulnerability, and disasters*. London: Routledge.
- Cardona, O. (2001). *La necesidad de repensar de manera holística los conceptos de vulnerabilidad y riesgo*. Paper presented at International Conference on Vulnerability in Disaster Theory and Practice, Wageningen University, Netherlands, June 2001.
- CEGIS (2002). *Analytical framework for the planning of integrated water resources management*. Center for Environmental and Geographic Information Systems, Dhaka.
- Centre for Policy Dialogue (2004). *Interim Report-Rapid Assessment of Flood 2004*. Dhaka, August 2004.
- Chambers, R. (1995). Poverty and livelihoods: whose reality counts? *Environment and Urbanization* 7(1), 173–204.
- Costanza, R. (1994). Three general policies to achieve sustainability. In Jansson, A-M., Hammer, M., Folke, C. & Costanza, R. (eds.). *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*. Washington DC: Island Press.
- Faber, M. & Proops, J.L.R. (1990). *Evolution, time, production and the environment*. Berlin: Springer.
- Few, R. (2003). Flooding, vulnerability and coping strategies: local responses to a global threat. *Progress in Development Studies*, 3(1), 43–58.
- Funtowicz, S.O. & Ravetz, J.R. (1992). Three types of risk assessment and the emergence of post-normal science. In: Krinsky, S. & Golding, D. (eds.). *Social theories of risk*, pp. 251–273. Westport, CT: Praeger.
- Haque, C.E. & Zaman, M.Q. (1994). Vulnerability and responses to riverine hazards in Bangladesh: A critique of flood control and mitigation approaches. In: Varley, A. (Ed). *Disasters, Development and the Environment*. New York: Wiley.
- Intergovernmental Panel on Climate Change (2001). *Climate change 2001: impacts, adaptation, and vulnerability*. Summary for policymakers. A Report of Working Group II of the IPCC. Geneva: IPCC.
- Knight, F.H. (1921). *Risk, Uncertainty, and Profit*. Boston: Houghton Mifflin.
- LCG Bangladesh (2004). *Post-flood needs assessment summary report*. Local Consultative Groups (LCG) Bangladesh, September 2004.
- Moser, C.O.N. (1998). The asset vulnerability framework: reassessing urban poverty reduction strategies. *World Development* 26(1), 1–19.
- Nishat, A., Reazuddin, M., Amin, R. & Khan, A.R. (eds.) (2000). *The 1998 flood: impact on environment of Dhaka city*. Dhaka: Department of Environment and IUCN Bangladesh.
- Pelling, M. (1999). The political ecology of flood hazard in urban Guyana. *Geoforum*, 30, 249–261.
- Quassem, M. A. (2001). *Water Institutions – Bangladesh Experience*. Dhaka, Bangladesh.

- Rashid, S.F. (2000). The urban poor in Dhaka city: their struggles and coping strategies during the floods of 1998. *Disasters* 24(3), 240–53.
- Rasid, H. (2000). Reducing vulnerability to flood disasters in Bangladesh: Compatibility of floodplain residents' preferences for flood alleviation measures with indigenous adjustments to floods. In: D.J. Parker (ed.). *Floods: Volume II*. pp. 46–65. London: Routledge.
- Rasid, H. & Haider, W. (2003). Floodplain residents' preferences for water level management options in flood control projects in Bangladesh. *Natural Hazards* 28, 101–129.
- Schmuck-Widmann, H. (1996). *Living with the floods: survival strategies of char-dwellers in Bangladesh*. Berlin: FDCL.
- Shogren, J. & T. Crocker (1991). Risk, self-protection, and ex ante valuation. *Journal of Environmental Economics and Management* 20, 1–15.
- Smith, V.K. (1992). Environmental risk perception and valuation: Conventional versus prospective reference theory. In: Bromley, D.W. & Segerson, K. (eds.). *The social response to environmental risk*. Boston: Kluwer.
- Vincent, K. (2004). *Creating an index of social vulnerability to climate change for Africa*. Working paper 56. Tyndall Centre for Climate Change Research, University of East Anglia, UK.
- Zaman, H. (1999). *Assessing the impact of micro-credit on poverty and vulnerability in Bangladesh*. World Bank Policy Research Working Paper, No. 2145. World Bank, Washington, July 1999.